US011662204B2

(12) **United States Patent**
Ogura et al.

(10) **Patent No.: US 11,662,204 B2**
(45) **Date of Patent: May 30, 2023**

(54) **VIBRATOR DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 371 days.

(21) Appl. No.: **17/155,418**

(22) Filed: **Jan. 22, 2021**

(65) **Prior Publication Data**

US 2021/0231438 A1 Jul. 29, 2021

(30) **Foreign Application Priority Data**

Jan. 24, 2020 (JP) JP2020-009799

(51) **Int. Cl.**
H03H 9/21 (2006.01)
G01C 19/5628 (2012.01)

(52) **U.S. Cl.**
CPC ***G01C 19/5628*** (2013.01); ***H03H 9/21*** (2013.01)

(58) **Field of Classification Search**
CPC G01C 19/5628
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,112,914 B1 * 9/2006 Dalla Piazza H03H 9/21 310/370
10,673,408 B2 * 6/2020 Goto B06B 1/0603
11,444,235 B2 * 9/2022 Ogura H10N 30/304
2009/0256449 A1 * 10/2009 Nishimura H03H 9/0519 29/25.35
2011/0221309 A1 * 9/2011 Umeki H03H 9/02023 29/25.35
2012/0043859 A1 * 2/2012 Ichikawa H03H 9/21 29/25.35
2013/0335157 A1 * 12/2013 Ishii H03H 9/1021 310/365
2018/0274922 A1 9/2018 Nishizawa et al.
2019/0101566 A1 * 4/2019 Inaba G01C 19/5628

FOREIGN PATENT DOCUMENTS

JP 2011-155339 8/2011
JP 2013-207527 10/2013
JP 2017092724 A * 5/2017
JP 2018-159674 10/2018

* cited by examiner

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(57) **ABSTRACT**

A vibrator device includes a vibrating body having a first surface, a package having a second surface opposed to the first surface of the vibrating body, a circuit board provided to the package so as to be opposed to the first surface of the vibrating body, a plurality of coupling electrodes provided to the first surface of the vibrating body, a first coupling line provided to the second surface of the package, a second coupling line provided to the circuit board, and a bonding material electrically coupling the coupling electrode and the first coupling line to each other, wherein the vibrating body has a protrusion protruding toward the package farther than the coupling electrode at the first surface side, and the protrusion has contact with the second surface of the package.

7 Claims, 11 Drawing Sheets

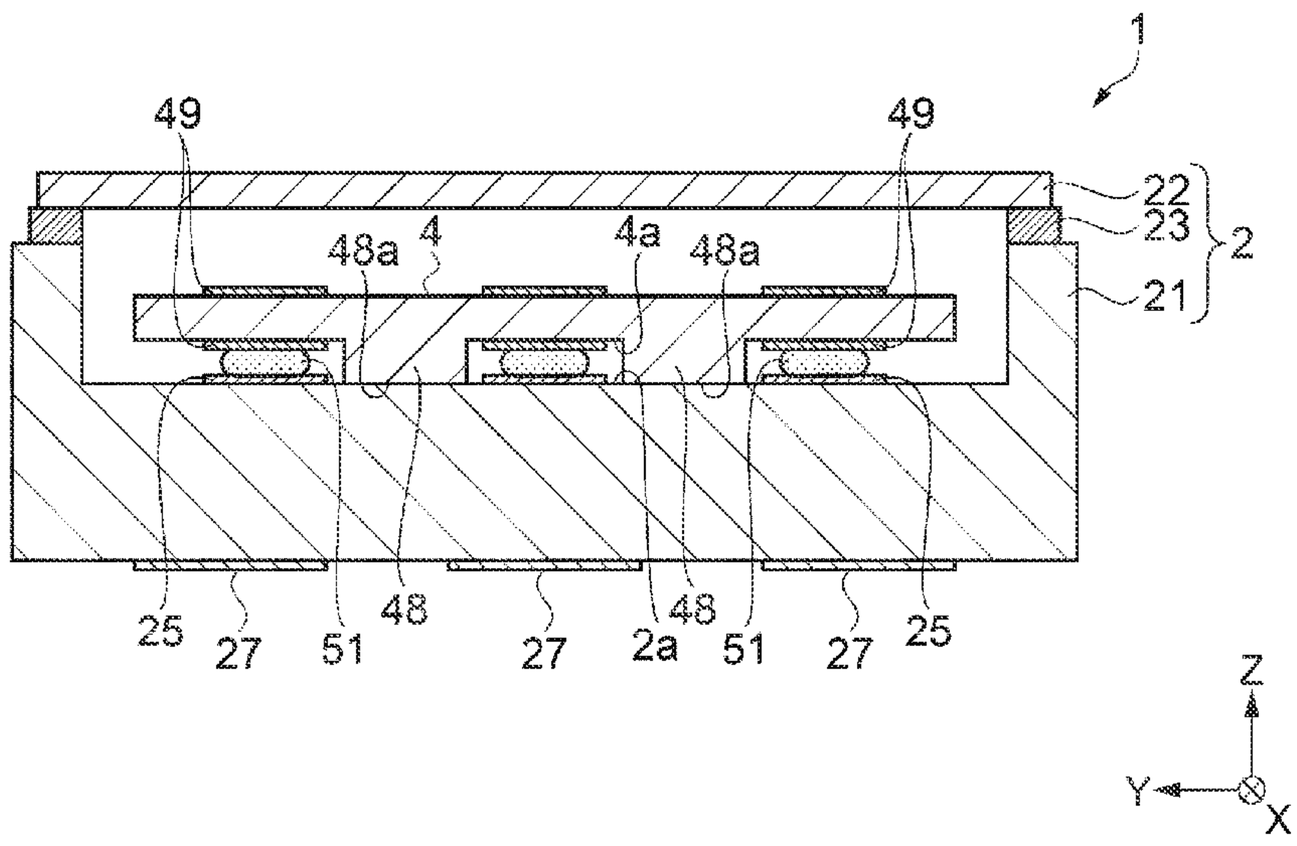

FIG. 1

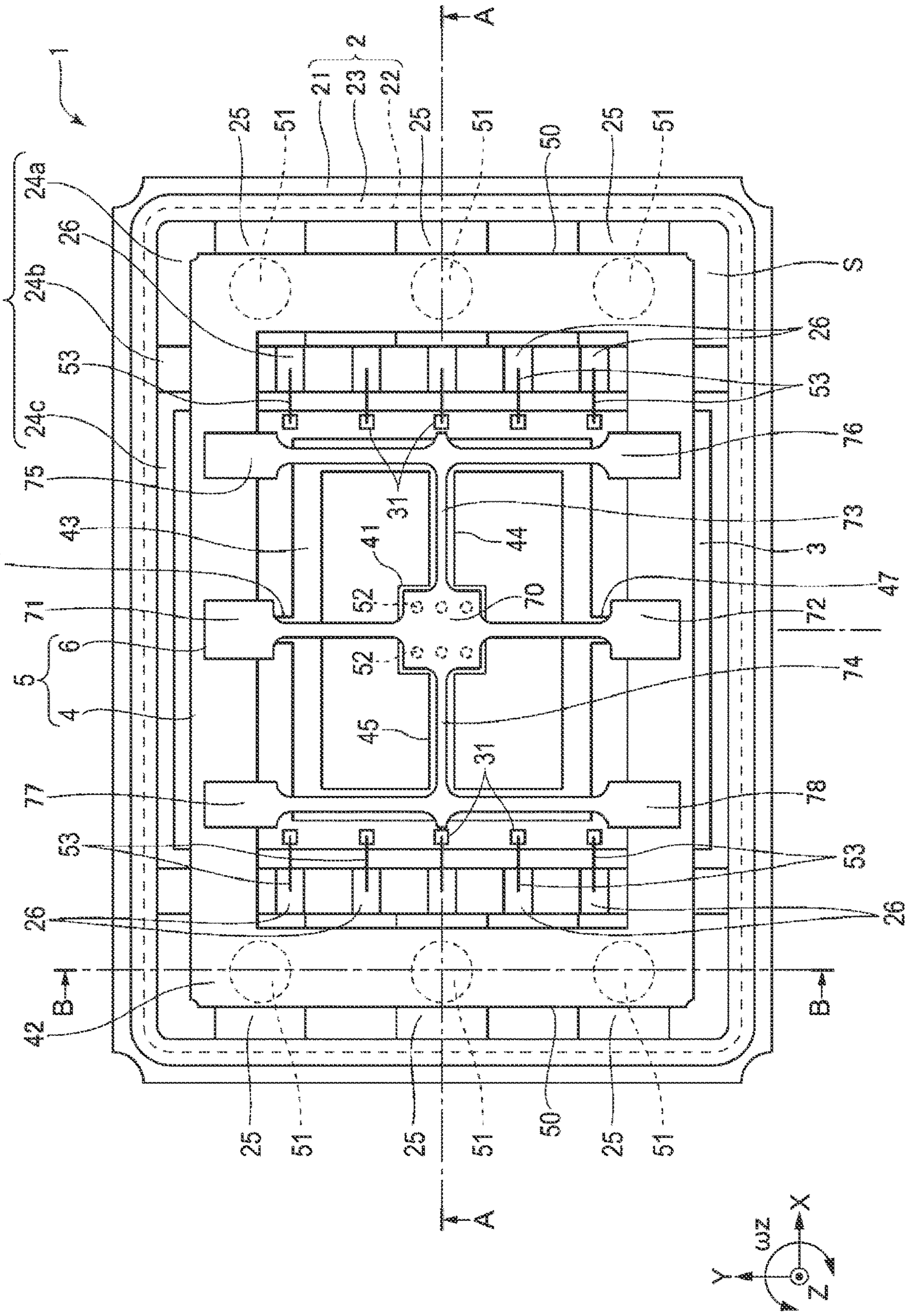
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FIG. 2

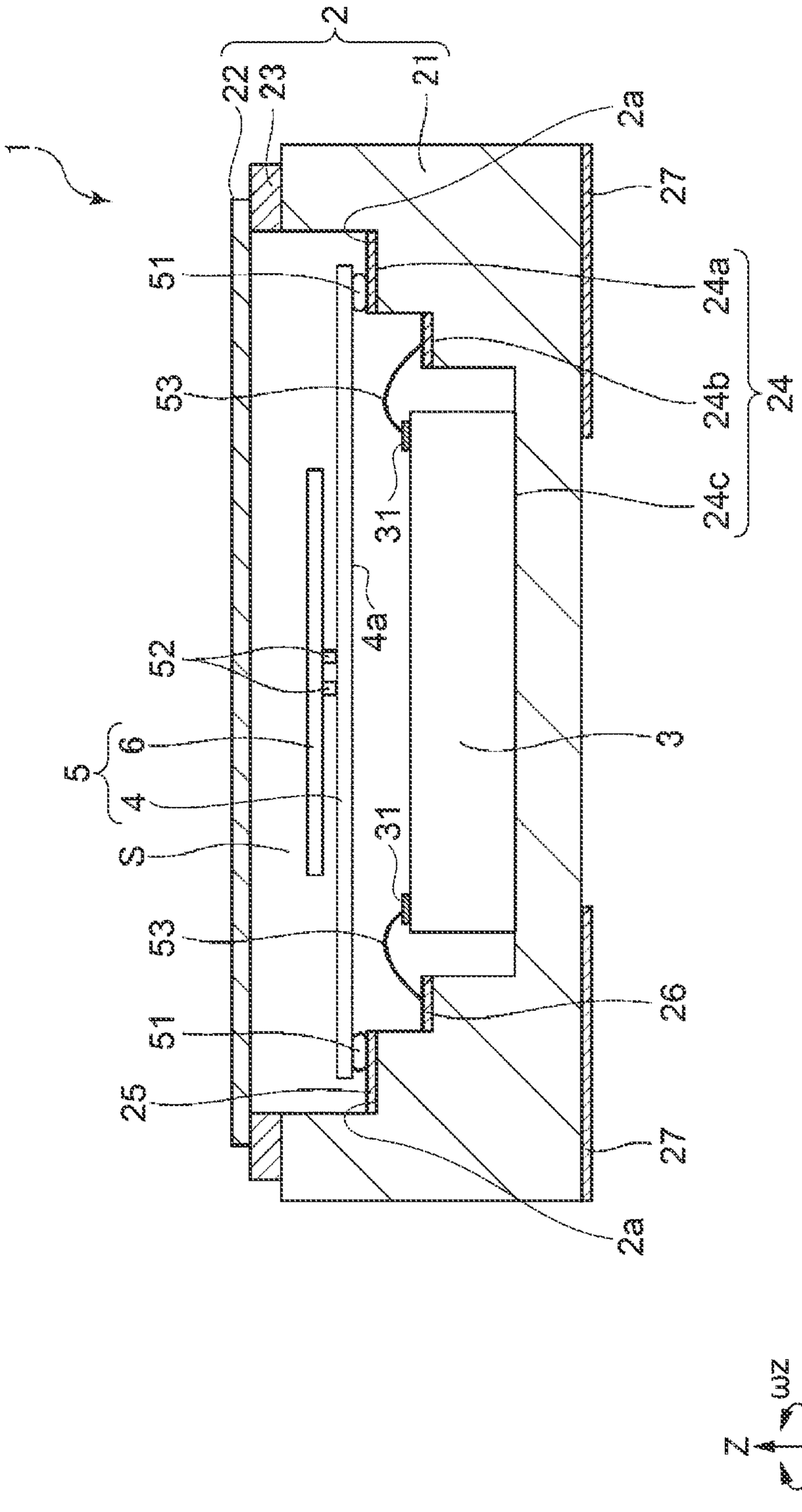
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FIG. 3

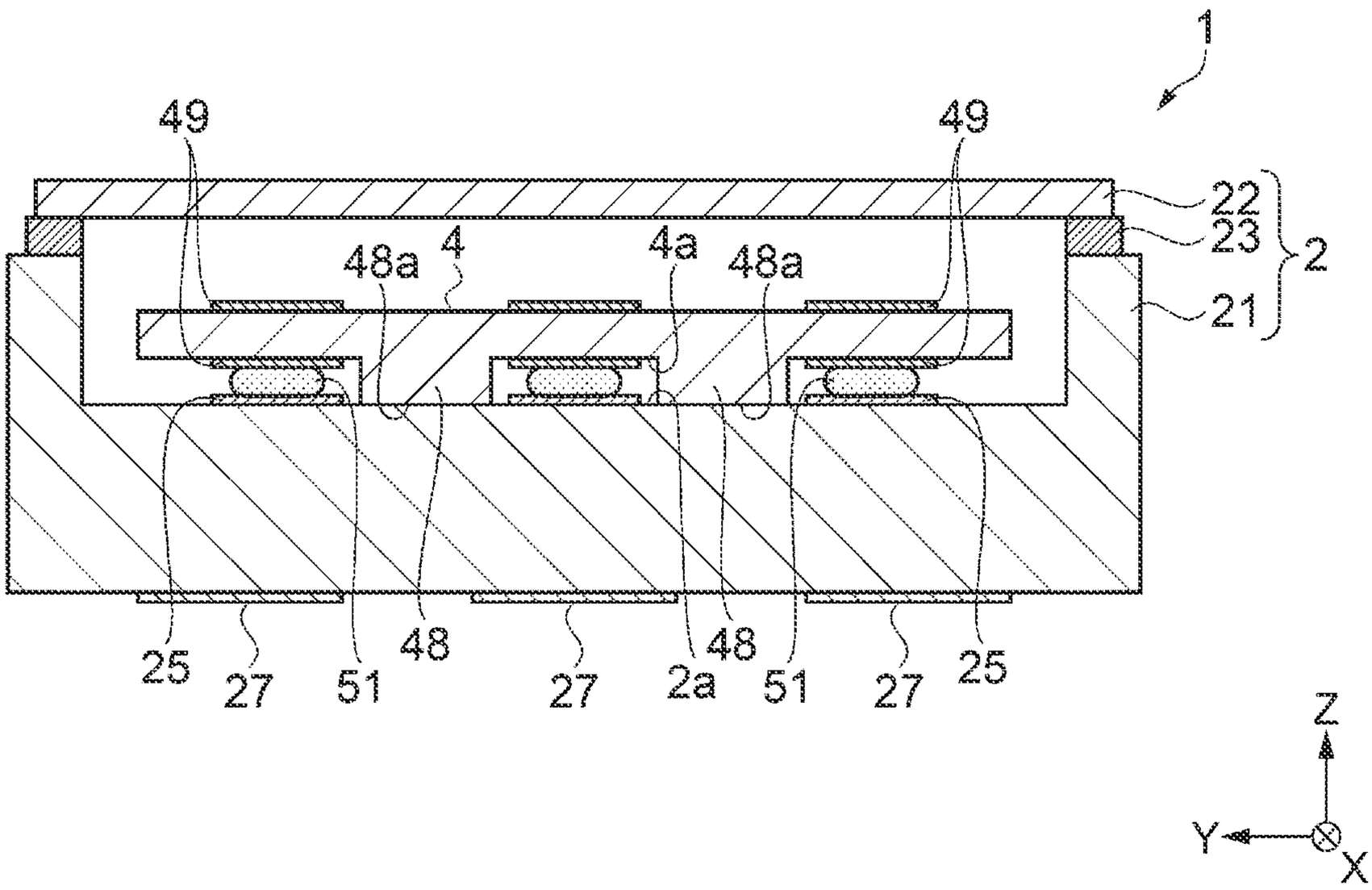
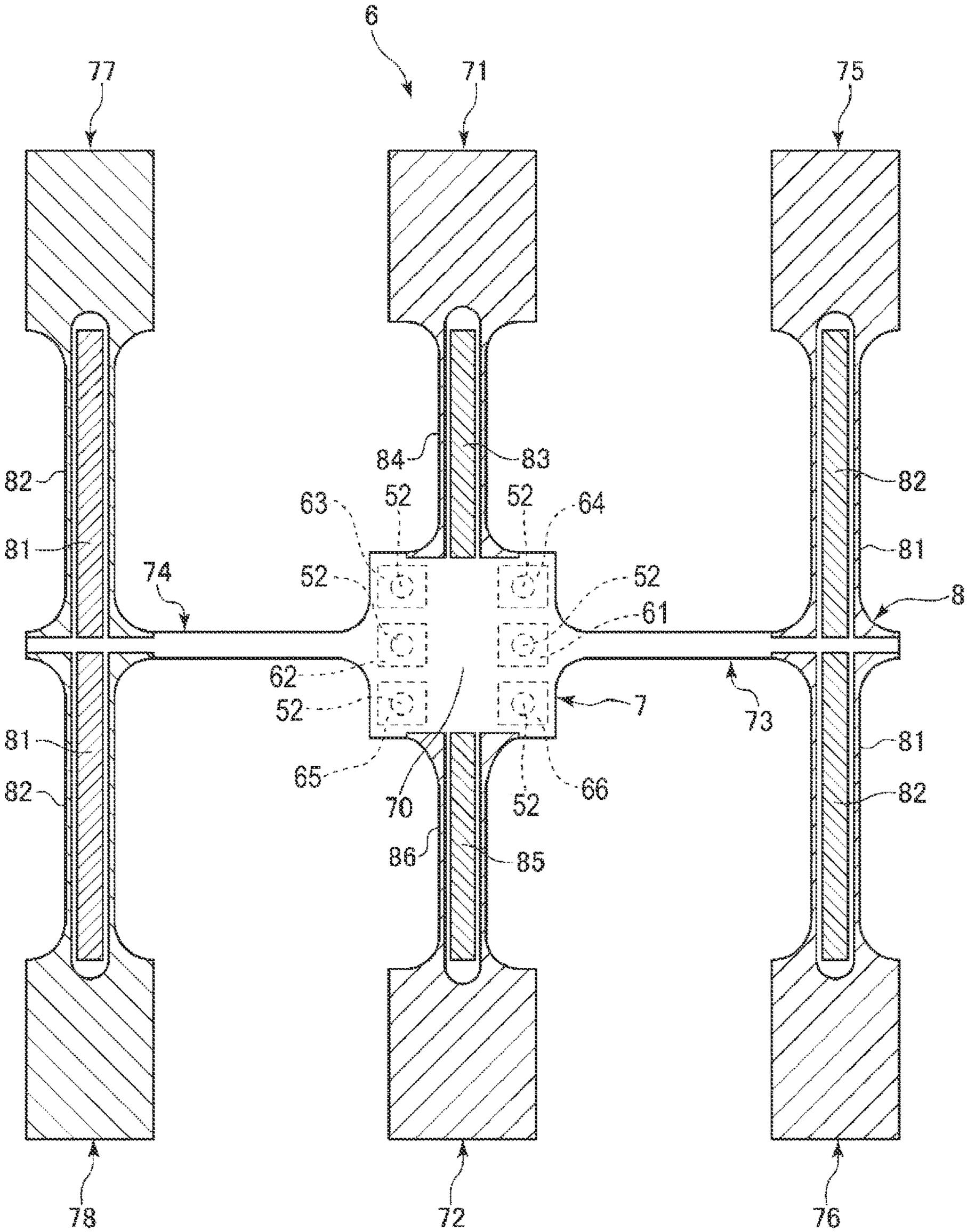


FIG. 4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7
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X
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FIG. 5

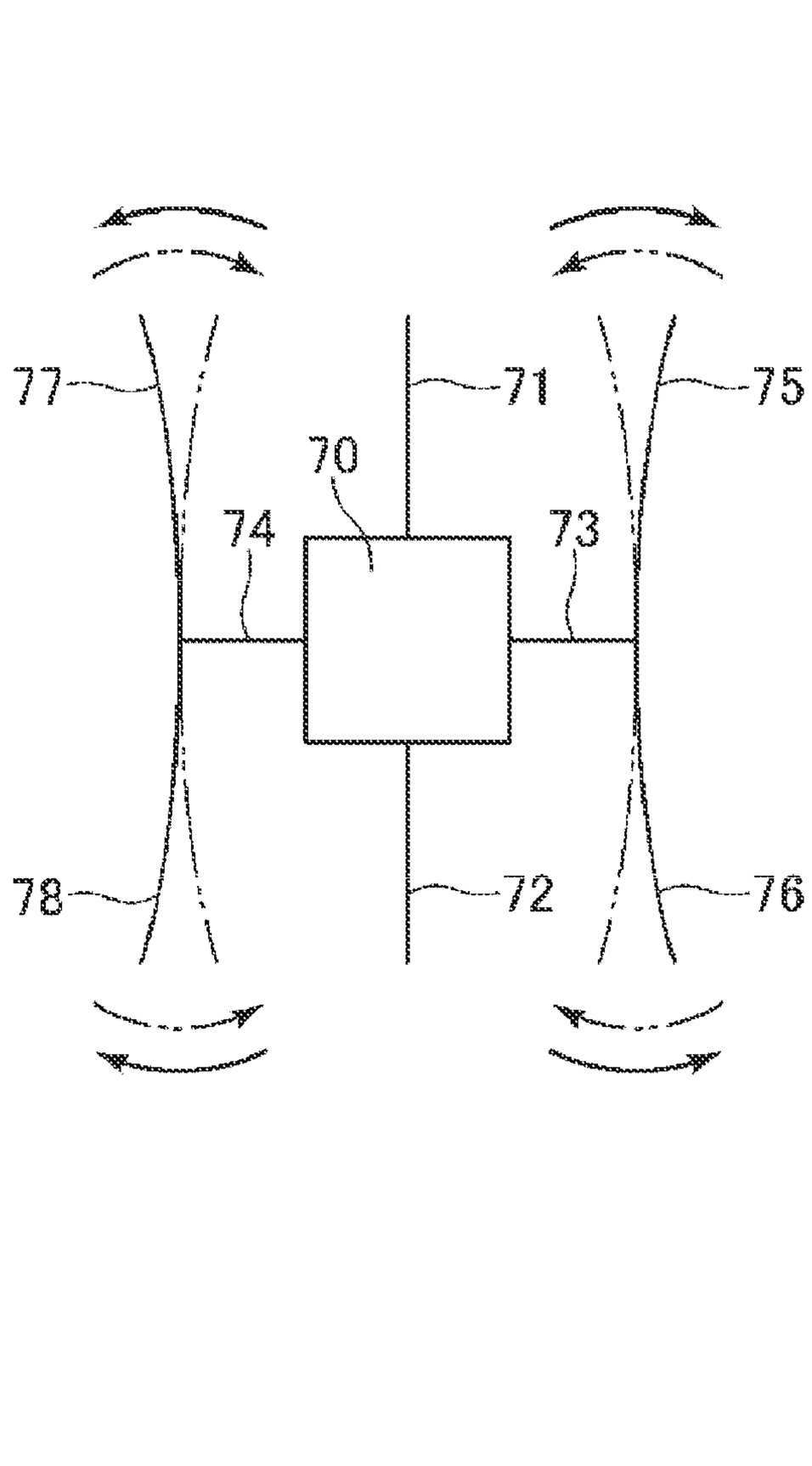


FIG. 6

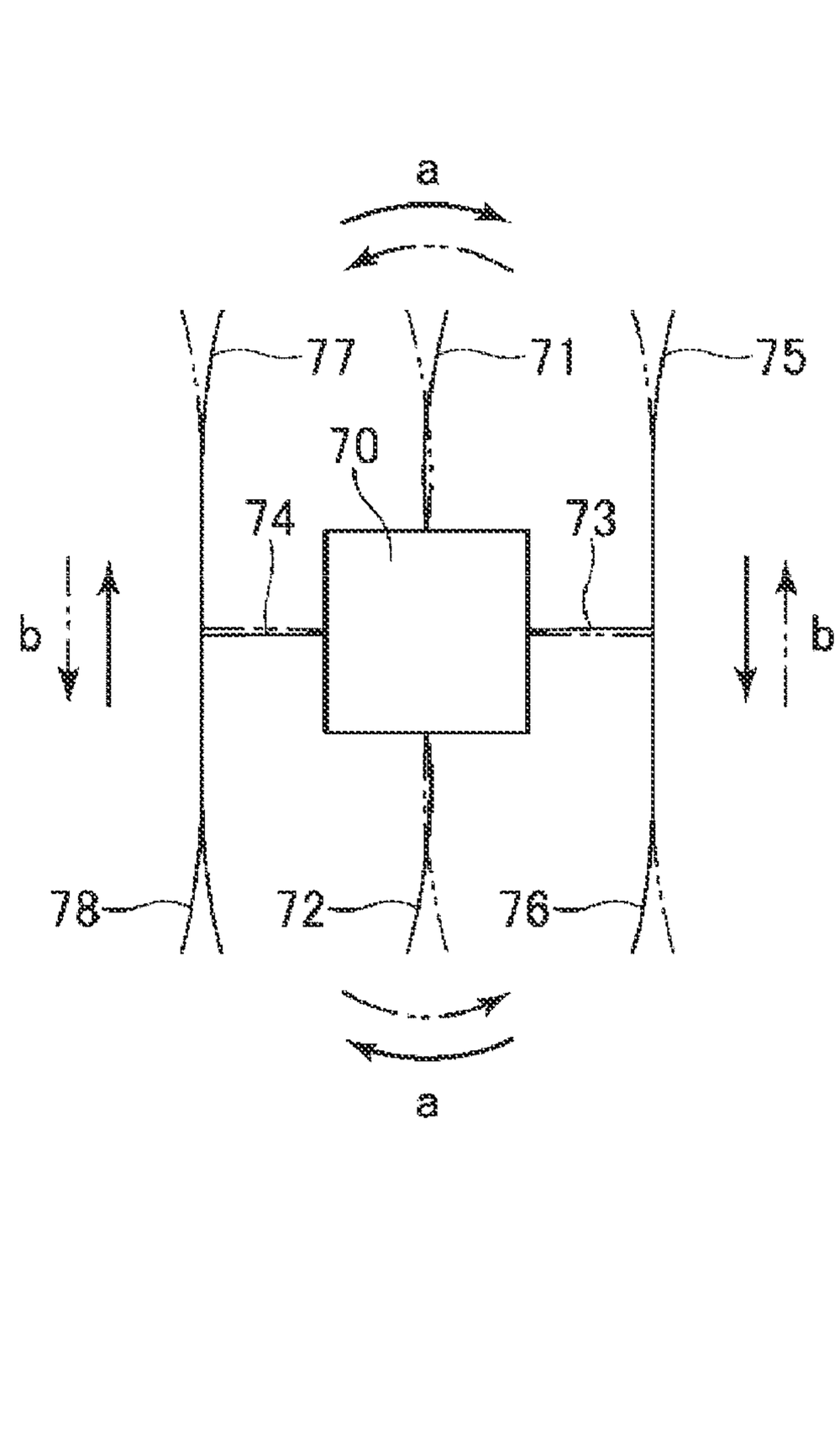
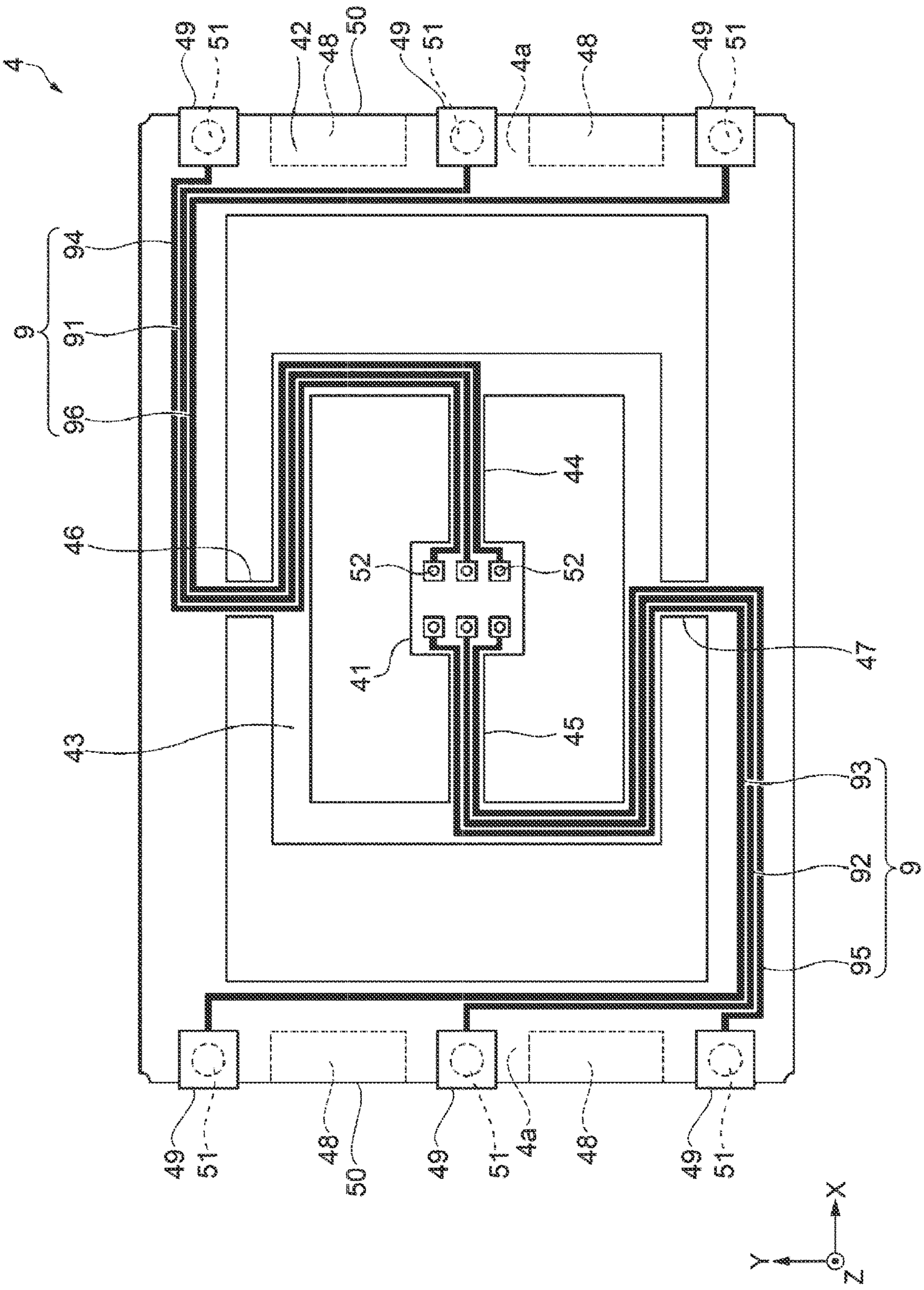


FIG. 7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94
91
96
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44
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47
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92
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51
X
Y
Z

FIG. 8

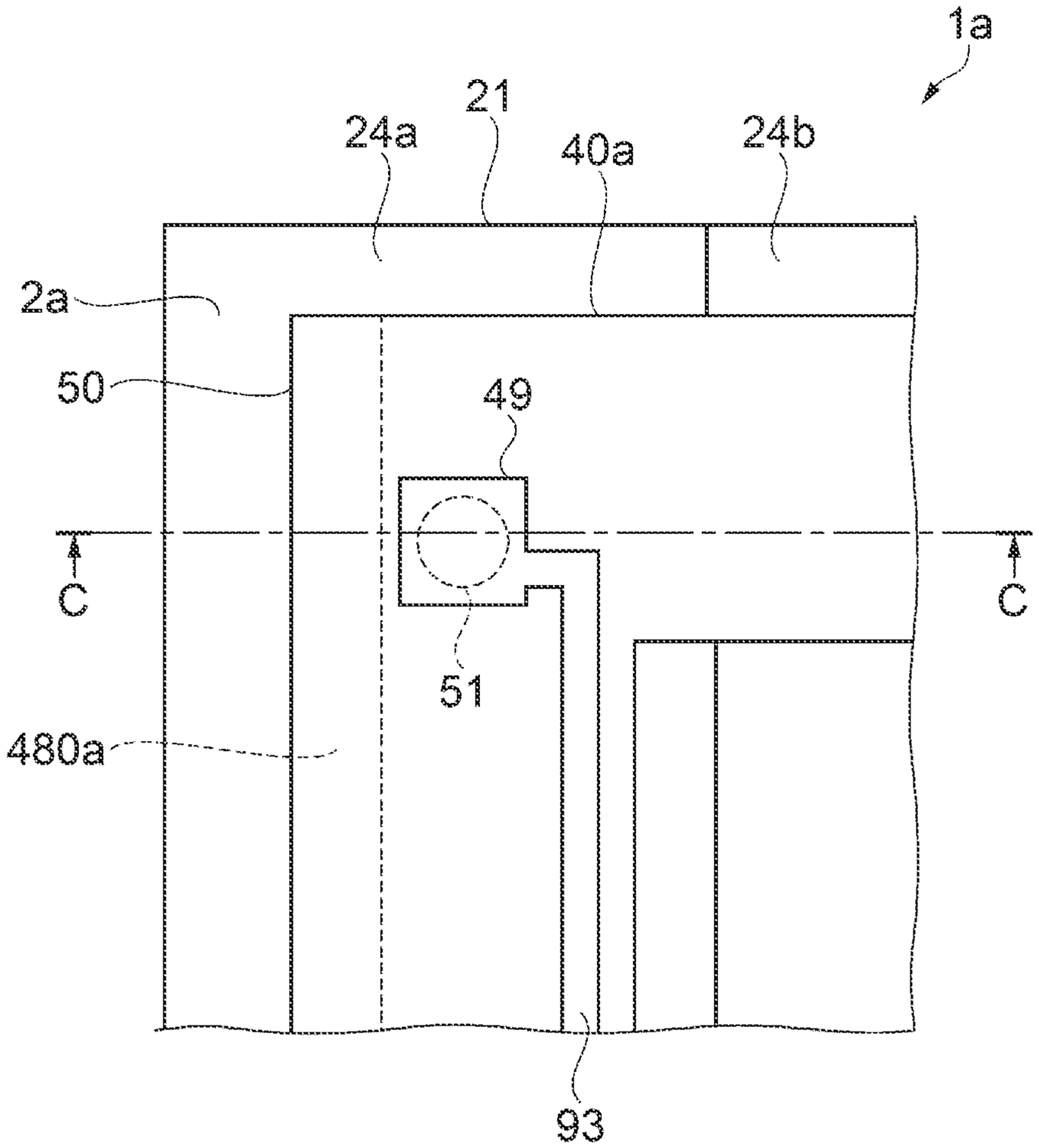


FIG. 9

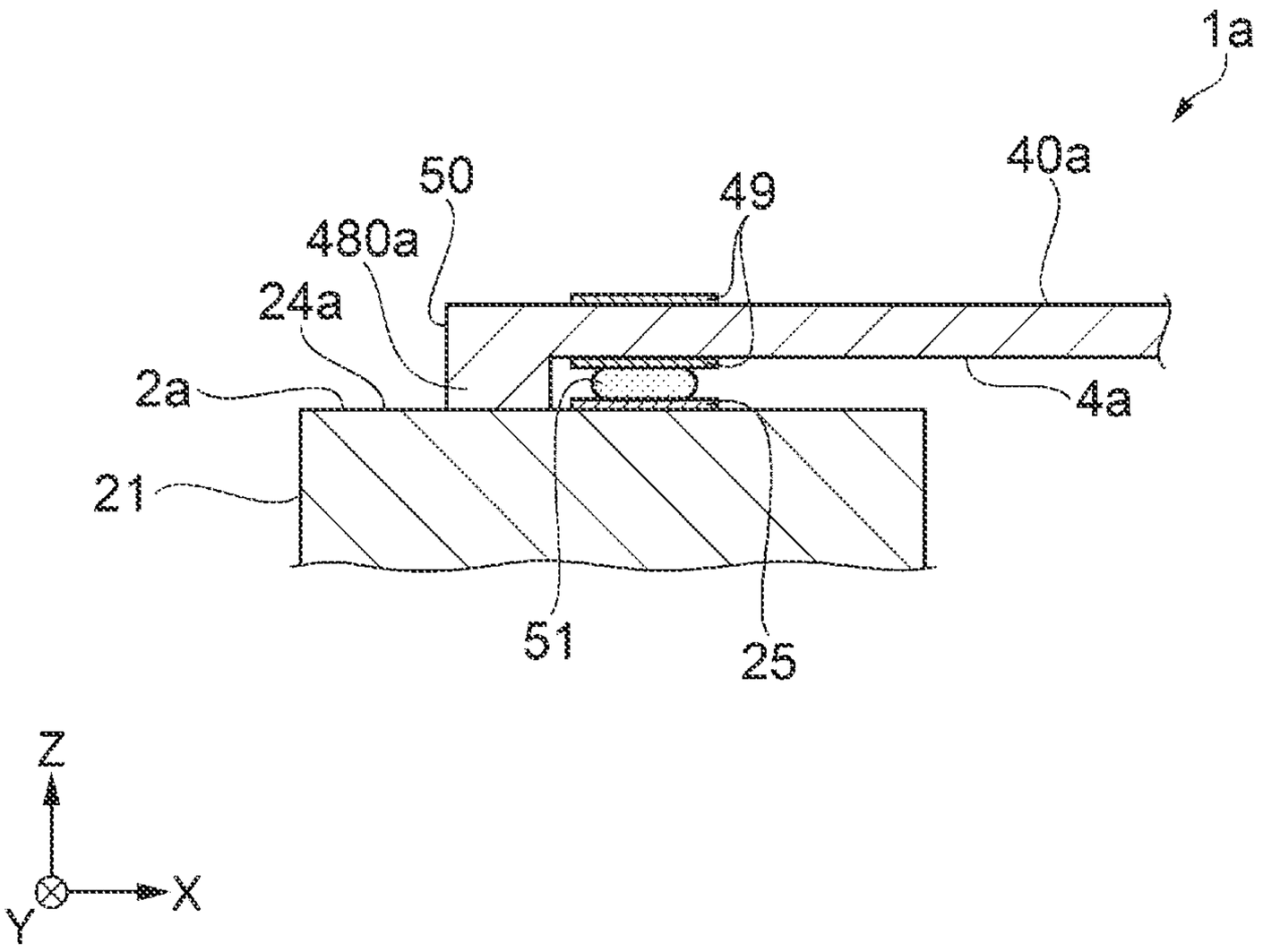


FIG. 10

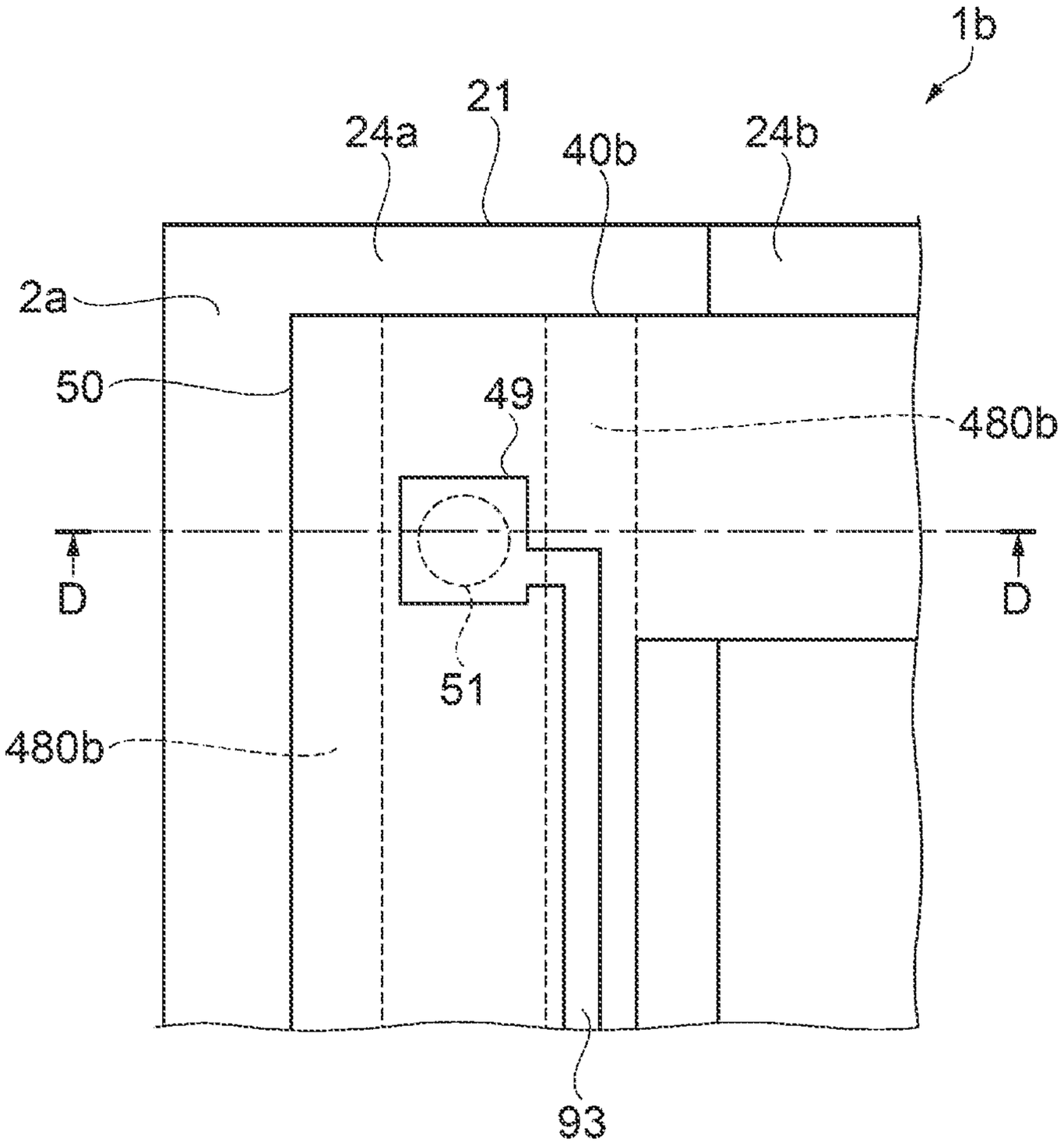
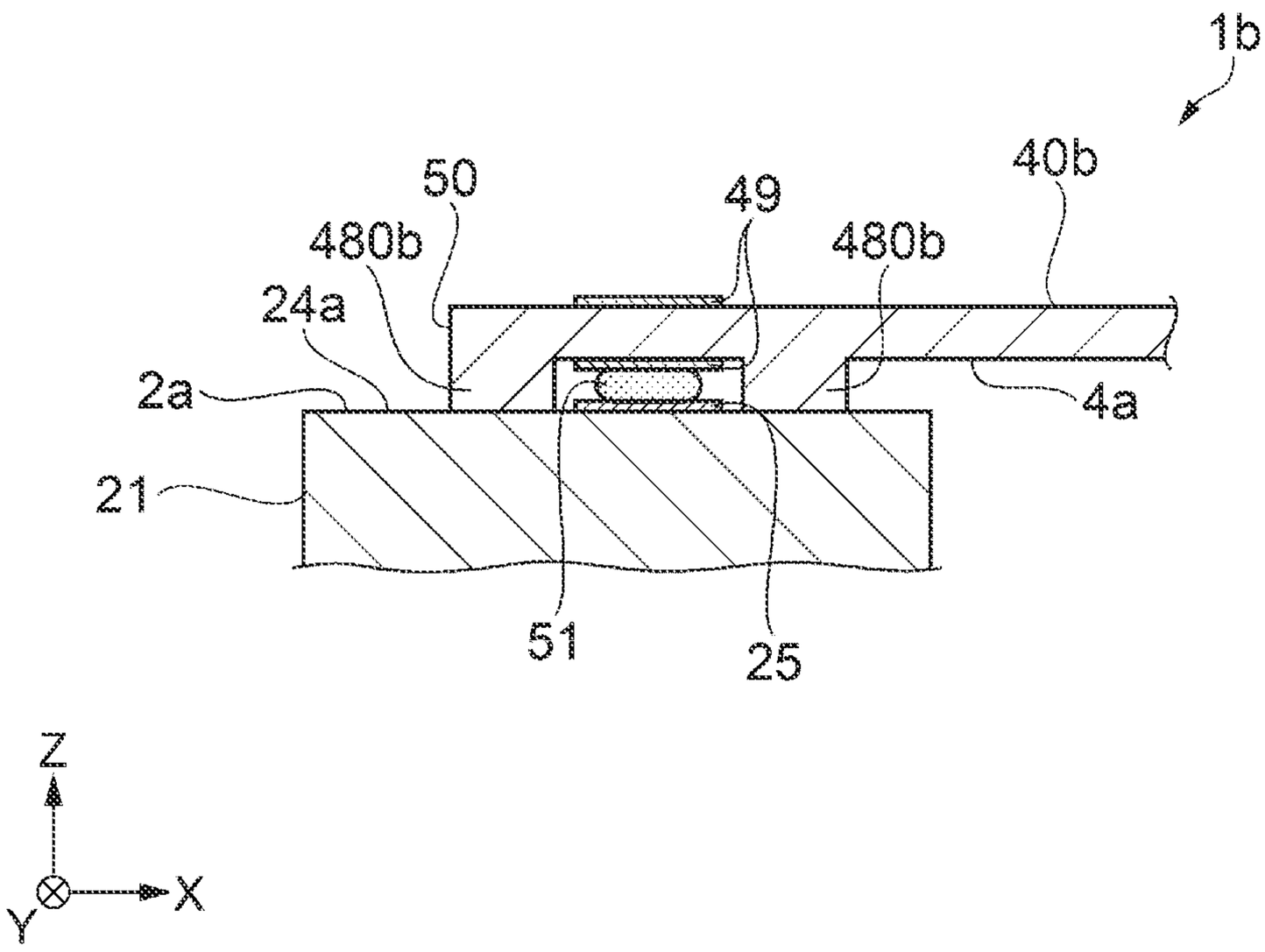


FIG. 11



VIBRATOR DEVICE

The present application is based on, and claims priority from JP Application Serial Number 2020-009799, filed Jan. 24, 2020, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to a vibrator device.

2. Related Art

In JP-A-2018-159674, there is disclosed a vibrator device which has a vibrator element, a relay substrate for supporting the vibrator element, and a package for fixing the relay substrate, and in which fixation parts provided to both ends of the relay substrate are fixed with an adhesive to an upper stage surface provided to a base member of the package to thereby reduce transmission of a thermal stress occurring in the package or a stress caused by an impact or the like received by the package to the vibrator element to reduce a variation of the vibration characteristics.

However, in the vibrator device described in Document 1, there is a possibility that the distance between the relay substrate and the package varies due to the variation in thickness of the adhesive when installing the relay substrate in the package. Therefore, there is a problem that capacitances occurring between electrode lines on the relay substrate and wiring lines in the package, and between the electrode lines on the relay substrate and wiring lines of a circuit board varies, and it is difficult to achieve a design taking the capacitances into consideration.

SUMMARY

A vibrator device includes a vibrating body having a first surface, a package having a second surface opposed to the first surface of the vibrating body, a circuit board provided to the package so as to be opposed to the first surface of the vibrating body, a plurality of coupling electrodes provided to the first surface of the vibrating body, a first coupling line provided to the second surface of the package, a second coupling line provided to the circuit board, and a bonding material electrically coupling the coupling electrode and the first coupling line to each other, wherein the vibrating body has a protrusion protruding toward the package farther than the coupling electrode at the first surface side, and the protrusion has contact with the second surface of the package.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view showing a schematic configuration of a vibrator device according to a first embodiment.

FIG. **2** is a cross-sectional view along the line A-A shown in FIG. **1**.

FIG. **3** is a cross-sectional view along the line B-B shown in FIG. **1**.

FIG. **4** is a plan view showing a vibrator element provided to a vibrating body shown in FIG. **1**.

FIG. **5** is a schematic diagram for explaining drive of the vibrator element shown in FIG. **4**.

FIG. **6** is a schematic diagram for explaining drive of the vibrator element shown in FIG. **4**.

FIG. **7** is a plan view showing a support substrate provided to the vibrating body shown in FIG. **1**.

FIG. **8** is a plan view showing a schematic configuration of a vibrator device according to a second embodiment.

FIG. **9** is a cross-sectional view along the line C-C shown in FIG. **8**.

FIG. **10** is a plan view showing a schematic configuration of a vibrator device according to a third embodiment.

FIG. **11** is a cross-sectional view along the line D-D shown in FIG. **10**.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

1. First Embodiment

First, a vibrator device **1** according to a first embodiment will be described with reference to FIG. **1** through FIG. **7** citing a vibrator device having the vibrating body having the vibrator element mounted on the support substrate as an example.

It should be noted that an X axis, a Y axis, and a Z axis in the drawings are axes perpendicular to each other, wherein a direction extending along the X axis is defined as an "X direction," a direction extending along the Y axis is defined as a "Y direction," and a direction extending along the Z axis is defined as a "Z direction," and directions with arrows are positive directions. Further, the description will be presented defining the positive direction in the Z direction as an "upper side," and the negative direction in the Z direction as a "lower side." Further, in FIG. **1**, a plan view seen through a lid **22** is used for the sake of convenience of explanation. Further, in FIG. **1** and FIG. **2**, wiring lines and electrodes provided to a support substrate **4** and a vibrator element **6** are omitted from the illustration.

The vibrator device **1** according to the present embodiment is a physical quantity sensor for detecting angular velocity ωz defining the Z axis as the detection axis. As shown in FIG. **1**, FIG. **2**, and FIG. **3**, the vibrator device **1** has a package **2**, and a vibrating body **5** and a circuit element **3** as a circuit board housed in the package **2**. It should be noted that the vibrating body **5** includes the support substrate **4** and the vibrator element **6**, wherein the vibrator element **6** is supported on the support substrate **4**.

The package **2** has a base **21** provided with a recessed part **24** opening in an upper surface, and the lid **22** which is bonded to an upper surface of a base **21** via a bonding member **23** so as to close the opening of the recessed part **24**. The recessed part **24** forms an internal space S inside the package **2**, and the vibrating body **5** and the circuit element **3** are housed in the internal space S. For example, the base **21** can be formed of ceramics such as alumina, and the lid **22** can be formed of a metal material such as kovar. It should be noted that the constituent materials of the base **21** and the lid **22** are not particularly limited.

The internal space S is airtightly sealed, and is set in a reduced-pressure state, and more preferably a state approximate to a vacuum state. Thus, the viscosity resistance reduces and the vibration characteristics of the vibrator element **6** are improved. It should be noted that the atmosphere in the internal space S is not particularly limited, but can be, for example, in the atmospheric pressure state or a pressurized state.

Further, the recessed part **24** is constituted by a plurality of recessed parts **24***a*, **24***b*, and **24***c* arranged side by side in the Z direction, and has the recessed part **24***a* opening in the upper surface of the base **21**, the recessed part **24***b* which

opens in a bottom surface of the recessed part **24***a* and is smaller in opening width than the recessed part **24***a*, and the recessed part **24***c* which opens in a bottom surface of the recessed part **24***b* and is smaller in opening width than the recessed part **24***b*. Further, to a second surface **2***a* as the bottom surface of the recessed part **24***a*, there is fixed the support substrate **4** for the vibrating body **5**, and to the bottom surface of the recessed part **24***c*, there is fixed the circuit element **3**.

Further, on the second surface **2***a* of the recessed part **24***a*, there is disposed internal terminals **25** as a plurality of first coupling lines, on the bottom surface of the recessed part **24***b*, there is disposed a plurality of internal terminals **26**, and on the lower surface of the base **21**, there is disposed a plurality of external terminals **27**. The internal terminals **25**, **26** and the external terminals **27** described above are electrically coupled to each other via wiring lines not shown formed inside the base **21**. Further, as shown in FIG. **3**, the internal terminals **25** are electrically coupled to terminals **49** as coupling electrodes provided to the support substrate **4** via bonding materials **51** having electrical conductivity. Further, the internal terminals **26** are electrically coupled to terminals **31** as second coupling lines disposed on the circuit element **3** via bonding wires **53**.

The circuit element **3** is fixed to the bottom surface of the recessed part **24***c*. The circuit element **3** includes a drive circuit for driving the vibrator element **6** and a detection circuit for detecting the angular velocity ωz applied to the vibrator element **6**.

As shown in FIG. **3**, in the vibrator device **1**, the terminals **49** provided to a first surface **4***a* of the support substrate **4** are fixed with the adhesive on the internal terminals **25** provided to the second surface **2***a* of the recessed part **24***a* via bonding materials **51** such as electrically-conductive adhesive. Further, the first surface **4***a* at both ends in the X direction of the support substrate **4** is provided with a plurality of protrusions **48** each protruding toward the package **2** farther than the terminals **49**, and a surface **48***a* of each of the protrusions **48** opposed to the second surface **2***a* of the recessed part **24***a* has contact with the second surface **2***a* of the recessed part **24***a* constituting the package **2**. It should be noted that the surface **48***a* having contact with the second surface **2***a* of the protrusion **48** is parallel to the second surface **2***a*.

Further, since the plurality of protrusions **48** is disposed along sides **50** at both ends of the support substrate **4**, by fixing with the adhesive the support substrate **4** and the recessed part **24***a* of the package **2** to each other in the state in which the surfaces **48***a* of the protrusions **48** have contact with the second surface **2***a* of the recessed part **24***a*, the protrusions **48** function as a stopper, and thus, the distance between the first surface **4***a* of the support substrate **4** and the bottom surface of the recessed part **24** in the package **2** can be made constant. Therefore, the capacitances formed between the plurality of terminals **49** provided to the first surface **4***a* of the support substrate **4** and the internal terminals **25** provided to the bottom surface of the recessed part **24***a* in the package **2**, and between a plurality of wiring lines **9** described later and provided to a surface at an opposite side to the first surface **4***a* of the support substrate **4** and terminals **31** of the circuit element **3** mounted on the bottom surface of the recessed part **24***c* in the package **2** can be made constant, and it becomes easy to achieve the design taking the capacitances into consideration.

The vibrating body **5** includes the vibrator element **6** and the support substrate **4** disposed between the vibrator element **6** and the package **2**, and supports the vibrator element **6** on the support substrate **4** via the bonding material **52** as shown in FIG. **2**.

The vibrator element **6** is an angular velocity sensor element capable of detecting the angular velocity ωz defining the Z axis as the detection axis as the physical quantity sensor element. As shown in FIG. **4**, the vibrator element **6** has a vibrating substrate **7**, and electrodes **8** disposed on a surface of the vibrating substrate **7**. The vibrating substrate **7** is formed of a Z-cut quartz crystal substrate. The Z-cut quartz crystal substrate has spread in an X-Y plane defined by an X axis as an electrical axis and a Y axis as a mechanical axis, and has a thickness in a direction along a Z axis as an optical axis, wherein the electrical axis, the mechanical axis, and the optical axis are crystal axes of quartz crystal.

The vibrating substrate **7** has a base part **70** located in a central portion, detection arms **71**, **72** as a pair of detection parts extending toward both sides in the Y direction from the base part **70**, a pair of coupling arms **73**, **74** extending toward both sides in the X direction from the base part **70**, drive arms **75**, **76** as a pair of drive parts extending toward both sides in the Y direction from a tip part of the coupling arm **73**, and drive arms **77**, **78** as a pair of drive parts extending toward both sides in the Y direction from a tip part of the coupling arm **74**.

As shown in FIG. **4**, the electrodes **8** include drive electrodes **81**, drive ground electrodes **82**, first detection electrodes **83** as detection electrodes, first detection ground electrodes **84**, second detection electrodes **85** as the detection electrodes, and second detection ground electrodes **86**.

The drive electrodes **81** are disposed on both side surfaces of each of the drive arms **75**, **76**, and an upper surface and a lower surface of each of the drive arms **77**, **78**. Meanwhile, the drive ground electrodes **82** are disposed on an upper surface and a lower surface of each of the drive arms **75**, **76**, and both side surfaces of each of the drive arms **77**, **78**. Further, the first detection electrodes **83** are disposed on an upper surface and a lower surface of the detection arm **71**, and the first detection ground electrodes **84** are disposed on both side surfaces of the detection arm **71**. Meanwhile, the second detection electrodes **85** are disposed on an upper surface and a lower surface of the detection arm **72**, and the second detection ground electrodes **86** are disposed on both side surfaces of the detection arm **72**.

Further, these electrodes **81** through **86** are each laid around to a lower surface of the base part **70**. Further, as shown in FIG. **4**, on the lower surface of the base part **70**, there are disposed a terminal **61** electrically coupled to the drive electrodes **81**, a terminal **62** electrically coupled to the drive ground electrodes **82**, a terminal **63** electrically coupled to the first detection electrodes **83**, a terminal **64** electrically coupled to the first detection ground electrodes **84**, a terminal **65** electrically coupled to the second detection electrodes **85**, and a terminal **66** electrically coupled to the second detection ground electrodes **86**.

Such a vibrator element **6** detects the angular velocity ωz in the following manner. First, when applying a drive signal between the drive electrodes **81** and the drive ground electrodes **82**, the drive arms **75** through **78** flexurally vibrate as represented by the arrows shown in FIG. **5**. Hereinafter, this drive mode is referred to as a drive vibration mode. Further, when the angular velocity ωz is applied to the vibrator element **6** in the state of performing the drive in the drive vibration mode, a detection vibration mode shown in FIG. **6** is newly excited. In the detection vibration mode, a Coriolis force acts on the drive arms **75** through **78**

to excite the vibration in a direction represented by the arrows b, and in concert with this vibration, the detection vibration due to the flexural vibration occurs in a direction represented by the arrows a in the detection arms **71**, **72**. A charge generated in the detection arm **71** due to such a detection vibration mode is taken out between the first detection electrodes **83** and the first detection ground electrodes **84** as a first detection signal, a charge generated in the detection arm **72** is taken out between the second detection electrodes **85** and the second detection ground electrodes **86** as a second detection signal, and it is possible to detect the angular velocity ωz based on these first and second detection signals.

The support substrate **4** is formed of the quartz crystal substrate with the same cutting angle as that in the vibrating substrate **7**. The support substrate **4** has a gimbal structure, and has an element mount part **41**, a support part **42**, a frame part **43**, a pair of inner beam parts **44**, **45**, and a pair of outer beam parts **46**, **47**, wherein the vibrator element **6** is mounted on the element mount part **41**, the support part **42** is located outside the element mount part **41**, fixed to the base **21**, and has a frame-like shape, the frame part **43** is located between the element mount part **41** and the support part **42**, and has a frame-like shape surrounding the element mount part **41**, the pair of inner beam parts **44**, **45** extend toward both sides in the X direction from the element mount part **41** to couple the element mount part **41** and the frame part **43** to each other, and the pair of outer beam parts **46**, **47** extend toward both sides in the Y direction from the frame part **43** to couple the frame part **43** and the support part **42** to each other in a plan view from the Z direction as shown in FIG. **7**.

Further, the support substrate **4** has the plurality of protrusions **48** protruding toward the negative Z direction at the first surface **4***a* side of both ends in the X direction of the support part **42**. The plurality of protrusions **48** is disposed along the sides **50** at the both ends of the support part **42** between the terminals **49** as the plurality of coupling electrodes.

Further, the support substrate **4** is provided with a plurality of wiring lines **9** electrically coupling the electrodes **81** through **86** of the vibrator element **6** and the internal terminals **25** in the package **2** to each other. The plurality of wiring lines **9** includes a drive wiring line **91** and a drive ground wiring line **92** as a drive wiring line, a first detection wiring line **93** as a detection wiring line, a first detection ground wiring line **94**, a second detection wiring line **95** as a detection wiring line, a second detection ground wiring line **96**, and the terminals **49**. Therefore, the support substrate **4** is provided with two driving wiring lines, four detecting wiring lines, and six terminals used for coupling to the internal terminals **25** in the package **2**. Further, these wiring lines **91** through **96** are each laid around to the element mount part **41** and the support part **42** through the inner beam parts **44**, **45**, the frame part **43**, and the outer beam parts **46**, **47**. It should be noted that the wiring lines **9** correspond to the coupling electrodes in the present embodiment.

Further, the drive wiring line **91** is electrically coupled to the terminal **61**, namely the drive electrodes **81**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**. Further, the drive ground wiring line **92** is electrically coupled to the terminal **62**, namely the drive ground electrodes **82**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**.

Further, the first detection wiring line **93** is electrically coupled to the terminal **63**, namely the first detection electrodes **83**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**. Further, the first detection ground wiring line **94** is electrically coupled to the terminal **64**, namely the first detection ground electrodes **84**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**.

Further, the second detection wiring line **95** is electrically coupled to the terminal **65**, namely the second detection electrodes **85**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**. Further, the second detection ground wiring line **96** is electrically coupled to the terminal **66**, namely the second detection ground electrodes **86**, via the bonding material **52** on the element mount part **41**, and is electrically coupled to the internal terminal **25** via the bonding material **51** in the terminal **49** disposed in the end part of the support part **42**.

Thus, the vibrator element **6** and the circuit element **3** are electrically coupled to each other via these wiring lines **91** through **96**. It should be noted that the bonding materials **51**, **52** are not particularly limited providing both of the electrical conductivity and the bonding property are provided, and there can be used, for example, an electrically-conductive adhesive, or a variety of types of metal bumps such as a gold bump or a solder bump.

Among the six wiring lines **91** through **96**, the drive wiring line **91**, the first detection ground wiring line **94**, and the second detection ground wiring line **96** are each laid around from the element mount part **41** to the terminal **49** disposed in the end part of the support part **42** through the inner beam part **44**, the frame part **43**, and the outer beam part **46**. Further, the drive ground wiring line **92**, the first detection wiring line **93**, and the second detection wiring line **95** are each laid around from the element mount part **41** to the terminal **49** disposed in the end part of the support part **42** through the inner beam part **45**, the frame part **43**, and the outer beam part **47**. It should be noted that the terminal **49** provided to the first surface **4***a* of the support substrate **4** and the terminal **49** provided to the surface at the opposite side to the first surface **4***a*, namely an upper surface of the support substrate **4**, are electrically coupled to each other with a side surface electrode provided to the side surface of the support substrate **4**.

In the vibrator device **1** according to the present embodiment, the first surface **4***a* opposed to the package **2** at both ends of the support substrate **4** supporting the vibrator element **6** is provided with the plurality of protrusions **48** each protruding toward the package **2** farther than the terminals **49**, and the surface **48***a* of each of the protrusions **48** opposed to the second surface **2***a* of the recessed part **24***a* has contact with the second surface **2***a* of the recessed part **24***a* constituting the package **2**. Therefore, by fixing with the adhesive the support substrate **4** and the recessed part **24***a* of the package **2**, the protrusions **48** function as the stopper, and the distance between the first surface **4***a* of the support substrate **4** and the bottom surface of the recessed part **24** in the package **2** can be made constant. Therefore, the capacitances formed between the coupling electrodes such as the

plurality of terminals **49** provided to the first surface **4***a* of the support substrate **4** and the first coupling lines such as the internal terminals **25** provided to the bottom surface of the recessed part **24***a* in the package **2**, and between the coupling electrodes such as the plurality of wiring lines **9** provided to the surface at the opposite side to the first surface **4***a* of the support substrate **4** and the second coupling lines such as the terminals **31** of the circuit element **3** mounted on the bottom surface of the recessed part **24***c* in the package **2** can be made constant, and it is possible to make it easy to achieve the design taking the capacitances into consideration.

Further, since the protrusions **48** are provided along the sides **50** at the both ends of the support substrate **4**, and are disposed between the terminals **49**, the support substrate **4** can be made parallel to the recessed part **24** in the package **2** in both of the X direction and the Y direction, namely the distance between the first surface **4***a* of the support substrate **4** and the bottom surface of the recessed part **24** in the package **2** can be made constant in both of the directions. Therefore, it is possible to further reduce the variation of the capacitances.

Further, since the surfaces **48***a* having contact with the second surface **2***a* of the protrusions **48** are parallel to the second surface **2***a*, the distance between the bottom surface of the recessed part **24** in the package **2** and the first surface **4***a* of the support substrate **4** can be made more constant and it is possible to further reduce the variation of the capacitances.

Further, since at least one of the terminals **49** is the drive wiring line **91** electrically coupled to the drive electrodes **81**, and at least one of the terminals **49** is one of the detection wiling lines **93**, **95** electrically coupled respectively to the detection electrodes **83**, **85**, it is possible to detect the angular velocity ωz by driving the drive parts of the vibrator element **6** with the circuit element **3** in the package **2** and then processing the detection signal output from the detection parts with the circuit element **3**.

2. Second Embodiment

Then, a vibrator device **1***a* according to a second embodiment will be described with reference to FIG. **8** and FIG. **9**. It should be noted that FIG. **8** and FIG. **9** correspond to apart located at the positive Y direction side and the negative X direction side out of the four corners inside the package **2** in FIG. **1**.

The vibrator device **1***a* according to the present embodiment is substantially the same as the vibrator device **1** according to the first embodiment except the fact that a structure of protrusions **480***a* of a support substrate **40***a* is different compared to the vibrator device **1** according to the first embodiment. It should be noted that the description will be presented with a focus on the difference from the first embodiment described above, and the description of substantially the same issues will be omitted.

As shown in FIG. **8** and FIG. **9**, the protrusions **480***a* provided to the support substrate **40***a* of the vibrator device **1***a* are disposed along the side **50** of the support substrate **40***a*, and each have a rectangular shape having long sides in the Y direction, and each protrude toward the negative Z direction. Further, the protrusion **480***a* is disposed between the side **50**, and the internal terminal **25** and the terminal **49** bonded to each other with the bonding material **51**. It should be noted that the protrusion **480***a* is also disposed between the side **50**, and the internal terminal **25** and the terminal **49** in the end part at the positive X direction side of the support substrate **40***a*.

By adopting such a configuration, there can be obtained substantially the same advantages as those of the vibrator device **1** according to the first embodiment.

3. Third Embodiment

Then, a vibrator device **1***b* according to a third embodiment will be described with reference to FIG. **10** and FIG. **11**. It should be noted that FIG. **10** and FIG. **11** correspond to a part located at the positive Y direction side and the negative X direction side out of the four corners inside the package **2** in FIG. **1** similarly to FIG. **8** and FIG. **9** described above.

The vibrator device **1***b* according to the present embodiment is substantially the same as the vibrator device **1** according to the first embodiment except the fact that a structure of a protrusion **480***b* of a support substrate **40***b* is different compared to the vibrator device **1** according to the first embodiment. It should be noted that the description will be presented with a focus on the difference from the first embodiment described above, and the description of substantially the same issues will be omitted.

As shown in FIG. **10** and FIG. **11**, the protrusions **480***b* provided to the support substrate **40***b* of the vibrator device **1***b* each have a rectangular shape having long sides in the Y direction, and each protrude toward the negative Z direction. Further, the protrusions **480***b* are disposed along the side **50** of the support substrate **40***b* at both sides in the X direction of the internal terminal **25** and the terminal **49** bonded to each other with the bonding material **51**. In other words, two protrusions **480***b* are disposed along the side **50** across the internal terminal **25** and the terminal **49**. It should be noted that the two protrusions **480***b* are also disposed across the internal terminal **25** and the terminal **49** in the end part at the positive X direction side of the support substrate **40***b*.

By adopting such a configuration, there can be obtained substantially the same advantages as those of the vibrator device **1** according to the first embodiment.

What is claimed is:

1. A vibrator device comprising:

a vibrating body having a first surface;

a package having a second surface opposed to the first surface of the vibrating body;

a circuit board provided to the package so as to be opposed to the first surface of the vibrating body;

a plurality of coupling electrodes provided to the first surface of the vibrating body;

a first coupling line provided to the second surface of the package;

a second coupling line provided to the circuit board; and

a bonding material electrically coupling the coupling electrode and the first coupling line to each other, wherein

the vibrating body has a protrusion protruding toward the package farther than the coupling electrode at the first surface side, and

the protrusion has contact with the second surface of the package.

2. The vibrator device according to claim **1**, wherein

the vibrating body includes

a drive part provided with a drive electrode, and

a detection part provided with a detection electrode,

at least one of the coupling electrodes is a drive wiring line electrically coupled to the drive electrode, and

at least one of the coupling electrodes is a detection wiring line electrically coupled to the detection electrode.

3. The vibrator device according to claim 1, wherein the protrusion is provided to each of both ends of the vibrating body.

4. The vibrator device according to claim 3, wherein a plurality of the protrusions is disposed along sides at the both ends of the vibrating body.

5. The vibrator device according to claim 3, wherein the protrusion is disposed between the coupling electrodes.

6. The vibrator device according to claim 1, wherein a surface of the protrusion having contact with the second surface is parallel to the second surface.

7. The vibrator device according to claim 1, wherein the vibrating body includes a vibrator element, and a support substrate disposed between the vibrator element and the package, and the protrusion is provided to the support substrate.

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